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TITLE: METHOD FOR ENCODING AND DECODING OBJECT AND DEVICE CAPABLE OF UTILIZING THE SAME

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ABSTRACT:

PROBLEM TO BE SOLVED: To exclude a difficulty in maintaining the fineness and high speed transmissivity of an object expressed with a polygon mesh.

SOLUTION: An object acquiring part 104 inputs the polygon mesh of the object. A function setting part 106 sets a function on a curved surface expressed by the polygon mesh. The function setting part 106 is provided with an origin defining part 108 for determining the origin of the function and a distance calculating part 110 for calculating a graph distance from a base apex to the respective apexes of the polygon mesh. On the basis of the graph distance, a shape element decomposing part 112 decomposes the polygon mesh into respective shape elements and an encoding part 114 encodes the respective shape elements.

NOTICES *

CLAIMS

[Claim(s)]
[Claim 1] An object coding method characterized by including a process which decomposes said curved surface to a configuration element which became independent, respectively, and a process which encodes said configuration element according to a process which acquires description of a curved surface of an object, a process which appoints a predetermined zero on said curved surface, and distance in which it results [from said zero] to each point on said curved surface.
[Claim 2] It is the method according to claim 1 of being the graph distance in which said description is made in a form of a polygon mesh, said zeros are predetermined base top-most vertices included in said polygon mesh, and said distance results [from said base top-most vertices] to each top-most vertices of said polygon mesh.
[Claim 3] Said configuration element is a method containing an outline graph which is the set of an edge from which graph distance connects equal top-most vertices, and is acquired according to claim 2.
[Claim 4] A method according to claim 3 of checking that subdivide said outline graph on an outline node and an outline edge, a method of an oiler applies an equation, and said object has justification as a closed surface.
[Claim 5] A method given in either of claims 2-4 which two or more said base top-most vertices are appointed, and define the minimum value as a graph distance of the top-most vertices among

graph distance in which it results [from these base top-most vertices] to a certain top-most
vertices.
[Claim 6] Said configuration element is a method given in either of claims 2-5 containing ANYURASU and a 2-dimensional cel.
[Claim 7] Said both ANYURASU and 2-dimensional cels are a method according to claim 6 set to
become a triangle strip.
[Claim 8] Said 2-dimensional cel is the method according to claim 7 of being the independent field
where the only borderline connects top-most vertices of graph distance m (however, m natural
number), and is acquired.
[Claim 9] Said ANYURASU is the method according to claim 7 of being the independent field
where one side of the two borderlines connects top-most vertices of graph distance m, and is
obtained, and another side connects top-most vertices of graph distance (m+1) (however, m natural
number), and is obtained.
[Claim 10] Said configuration element is a method given in either of claims 2-9 including global
topology of said object.
[Claim 11] Said global topology is a method according to claim 10 shown by structure graph
obtained based on said graph distance.
[Claim 12] Said structure graph is the method according to claim 11 of being the REBU graph with
which at least differential is known in phase geometry.
[Claim 13] Said coding is a method given in either of claims 2-12 including coding of local
topology of coding of geometric information on said object, and said object.
[Claim 14] Coding of said local topology is a method including description for identifying it, when
a configuration expressed with said polygon mesh is a non-manifold according to claim 13.
[Claim 15] A method according to claim 14 of describing that said object is a non-manifold by
describing the number of sets of a polygon gathering in top-most vertices used as a cause which
said non-manifold produces.
[Claim 16] Coding of said geometric information is a method given in either of claims 13-15
performed by being adapted for local magnitude of said polygon mesh.
[Claim 17] Coding of said geometric information is a method given in either of claims 13-16

performed by carrying out entropy code modulation of the difference of a forecast and an actual value of a certain attention geometry information.

[Claim 18] A method according to claim 17 by which said difference is beforehand adjusted so that said entropy code modulation may be optimized.

[Claim 19] Said adjustment is a method according to claim 18 performed by setting a predetermined permitted region as said actual value, detecting a reference value with which the amount of signs of difference with said forecast becomes the minimum in said permitted region, and replacing difference of said forecast and said actual value by difference of said forecast and said reference value.

[Claim 20] Said allowance area size is a method according to claim 19 been [a method / it] adapted and set to magnitude of a polygon mesh near a said attention geometry information's existence location.

[Claim 21] An object decode method characterized by to include a process which extracts a coding configuration element which was encoded after being decomposed according to distance in which it results to each point on the curved surface from a zero on a process which acquires coded data which describes a curved surface of an object, and said curved surface included in said coded data, and which becomes independent, respectively, and a process which decodes said coding configuration element.

[Claim 22] Object coding equipment characterized by including a unit which decomposes said curved surface to a configuration element which became independent, respectively, and a unit which encodes said configuration element according to a unit which acquires description of a curved surface of an object, a unit which appoints a zero on said curved surface, and distance in which it results [from said zero] to each point on said curved surface.

[Claim 23] It is equipment according to claim 22 which is the graph distance in which said description is made in a form of a polygon mesh, said zeros are predetermined base top-most vertices included in said polygon mesh, and said distance results [from said base top-most vertices] to each top-most vertices of said polygon mesh.

[Claim 24] Said configuration element is equipment given in either of claims 22 and 23 decomposed so that it may include global topology of said object.
[Claim 25] Said unit to encode is equipment given in either of claims 22-24 containing a unit which encodes geometric information on said object, and a unit which encodes local topology of said object.
[Claim 26] Object decode equipment characterized by to include a unit which extracts a coding configuration element which was encoded after being decomposed according to distance in which it results to each point on the curved surface from a zero on a unit which acquires coded data which describes a curved surface of an object, and said curved surface included in said coded data, and which becomes independent, respectively, and a unit which decodes said coding configuration element.
[Claim 27] An object coding method characterized by including a process which acquires an object, a process which defines a function about distance on a curved surface of said object, a process which acquires structure graph of said object based on a value of said function, and a process which encodes said object in a form where said structure graph is inherent.
[Claim 28] It is the method according to claim 27 which said object is expressed in a polygon mesh and outputs graph distance in which it results to each top-most vertices from predetermined base top-most vertices where said function is contained in said polygon mesh.
[Claim 29] Said structure graph is a method given in either of claims 27 and 28 expressed considering the singular point of said function as a node.

[Translation done.]

NOTICES *

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1.This document has been translated by computer. So the translation may not reflect the original
precisely.
2.**** shows the word which can not be translated.
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DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[The technical field to which invention belongs] This invention relates to object coding and
decode technology. Especially this invention relates to the method and equipment which encode
efficiently and decode the curved surface of the object described by the polygon mesh etc.
[0002]
[Description of the Prior Art] The spread of the Internet gave the opportunity to access information
huge to people without special equipment. The electronic commerce using the Internet is going to
progress quickly as this convenience is understood. The on-line shopping which exhibits a goods
catalog and receives an order especially attracts attention as an intelligible use of electronic
commerce.
[0003] The important requirements for on-line shopping are how to show goods attractively.
Although the catalog by the photograph is an effective means, when a user wants to look at the
goods from various directions, it is difficult to fill the want with a 2-dimensional photograph.
Therefore, recently, the modeling of the goods is beforehand recarried out in the form of polygon
data, and there is a motion considered so that a user can do actuation of amplification, a
revolution, etc. freely in three dimensions.
[0004]
[Problem(s) to be Solved by the Invention] However, when goods are polygonized for this object,

that amount of data becomes a problem. It is necessary to show especially goods delicately, therefore required polygon data may amount to several megabytes with one goods. Now, the sensation which winds freely the page of the conventional catalog which is paper data medium is not acquired. **** of on-line shopping is it to be [how a goods image can be transmitted and displayed quickly and] storable in the recording device to which a desired image and a desired three-dimensions configuration were restricted however.

[0005] This invention was made in view of such the actual condition, and the object is in offer of the technology which compresses and decodes the polygon mesh data of objects, such as goods.

[0006] In case another object of this invention compresses polygon data, it is in offer of the technology of giving a useful index to a next search etc. at the object, simultaneously.

[0007] Still more nearly another object of this invention has the decode time amount in short compression and offer of decode technology, when [at which the compressed polygon data is returned] decoding at the time that is,.

[0008] Still more nearly another object of this invention is in offer of the technology which compresses correctly a polygonization object with the constructional detail which cannot exist, and decodes it actually.

[0009]

[Means for Solving the Problem] An object coding method of this invention includes a process which decomposes said curved surface to a configuration element which became independent, respectively, and a process which encodes said configuration element according to a process which acquires description of a curved surface of an object, a process which appoints a predetermined zero on said curved surface, and distance in which it results [from said zero] to each point on said curved surface. When described in a form where an object is a polygon mesh, said zeros may be predetermined base top-most vertices included in said polygon mesh, and said distance may be a graph distance in which it results [from said base top-most vertices] to each top-most vertices of said polygon mesh.

[0010] Graph distance becomes settled by the number of edges (side) which result for example, from base top-most vertices to a certain top-most vertices. A configuration element may also contain an outline graph of an object which is the set of an edge from which graph distance from base top-most vertices connects equal top-most vertices, and is acquired. Speaking roughly, each configuration element's serving as an independent field which slices an object and is obtained centering on base top-most vertices, for example.
[0011] If a concept of distance, especially graph distance is introduced, it will become comparatively easy to decompose an object to a configuration element uniformly. Moreover, since each configuration element is the independent field, it becomes comparatively easy [coding].
[0012] A configuration element may also include global topology of an object. Global topology is the meaning except local topology like an initial entry between polygon top-most vertices. There is structure graph or a frame graph obtained as global topology based on graph distance. Global topology is useful to a next search etc. as an index of an object.
[0013] Coding includes coding of local topology of coding of geometric information on an object, and an object. As local topology, there is an initial entry between polygon top-most vertices. Coding of topology may also include description to that effect, when a configuration expressed with said polygon mesh is a non-manifold. The number of sets of polygons, such as the number of fields gathering in top-most vertices used as a cause which a non-manifold produces in that case, and a triangle, may be described.
[0014] Coding of geometric information may be performed by being adapted for local magnitude of a polygon mesh. As an example, entropy code modulation of the difference of a prediction location and an actual location of a certain attention top-most vertices is carried out. Under the present circumstances, said difference is beforehand adjusted so that entropy code modulation may be optimized. Although geometric information is related with a coordinate, it includes information, such as others, top-most vertices, and a color of a field or a normal. In that case, what is necessary

is just to carry out entropy code modulation of the difference of a forecast and an actual value of attention geometry information.

[0015] The object decode method of this invention can be used combining the object coding method of this invention, and includes the process which extracts the coding configuration element which was encoded after being decomposed according to distance in which it results to each point on the curved surface from a zero on a process which acquires coded data which describes a curved surface of an object, and said curved surface included in said coded data, and which becomes independent, respectively, and the process which decode said coding configuration element.

[0016] Object coding equipment of this invention materializes an above-mentioned object coding method, and contains a unit which decomposes said curved surface to a configuration element which became independent, respectively, and a unit which encodes said configuration element according to a unit which acquires description of a curved surface of an object, a unit which appoints a predetermined zero on said curved surface, and distance in which it results [from said zero] to each point on said curved surface.

[0017] Object decode equipment of this invention is what materializes an above-mentioned object decode method, and can be used combining the above-mentioned object coding equipment. A unit which acquires coded data which describes a curved surface of an object, A unit which extracts a coding configuration element which was encoded after being decomposed according to distance in which it results to each point on the curved surface from a zero on said curved surface included in said coded data, and which becomes independent, respectively, and a unit which decodes said coding configuration element are included.

[0018] Another gestalt of an object coding method of this invention includes a process which acquires an object, a process which defines a function about distance on a curved surface of said object, a process which acquires structure graph of said object based on a value of said function,

and a process at which said structure graph encodes said object clearly so that it may be inherent in behind implicitly in the condition in which reconstruction or reference is possible. When an object is expressed in a polygon mesh, said function may output the number of polygon edges which result to each top-most vertices from predetermined base top-most vertices included in said polygon mesh. In addition, an outline of the above invention is not what enumerated all the features required for this invention, and though natural, a subcombination of these characterizing group can also be invented.

[0019]

[Embodiment of the Invention] Hereafter, this invention is explained through the gestalt of implementation of invention. However, not all the combination of the feature of the gestalt of the following operations that do not limit invention indicated by the claim and are explained in the gestalt of operation is necessarily indispensable for the solution means of invention.

[0020] It is useful to explain the content of the paper which it faced to understand gestalt invention of operation and this invention person released previously as "premise technology." This premise technology is some papers (University of Tokyo doctoral dissertation 1993 Yoshihisa Shinagawa) of one of this invention persons. Hereafter, after quoting premise technology, an operation gestalt is explained in the form where correction or an escape is added to the premise technology.

[0021] [Premise technology]

[1] When encoding the configuration of the object in three-dimensions space, i.e., a solid, and a curved surface at the beginning of a curved-surface coding system (1) based on the Morse theory, usually express these as an array of a certain mark. It says expressing the object for information [modeling] being encoded here. As for the case of the object looked at by the nature, a configuration has very much flexibility. Therefore, in the case of coding, fixed simplification is needed. Topology (topology) is a mathematical means for performing such simplification.

[0022] This system interprets a three-dimensions body by using Morse (Morse) theory in topology

as a mathematical tool. Like the after-mentioned, this theory can perform the modeling of an object that there is [very efficiently and] no conflict. However, in order to encode the curved surface of three dimensions with perfect accuracy, just the Morse theory is inadequate. Hereafter, that reason is explained and the dissolution of this problem is aimed at by extending the Morse theory.

[0023] (2) the Morse theory -- a basis -- the Morse theory was advocated in order to deal with a calculus of variations. And the object suited describing the minimal value of the functional in the space of the path of an infinite dimension. It becomes possible by using the minimal value of a functional for reverse from this to describe the phase-feature of space for which description by the other method is difficult. Hereafter, the outline of the Morse theory is explained.

[0024] O The space which can apply the differentiable manifold Morse theory is a differentiable manifold. The manifold of a finite dimension is considered. Now, about the integer n of arbitration, a n-dimensional manifold is phase space and also carries out suddenly near which all points can map in one to one and both continuation on the subset of n-space Rn there. Such a map is called a "chart" and offers a local coordinates system about the point included to the field. If the earth is taken for an example, the LAT and LONG will hit a local coordinates system. In order for the manifold to be differentiable p times, the conversion to the system of coordinates of another side from one system of coordinates must be differentiable p times about the point included in the range of two different charts.

[0025] For this reason, it is possible that the manifold consists of fields of Rn which overlapped in good differential. For example, a straight line and a periphery can give the structure of a single dimension manifold. Moreover, the front face of a ball can be expressed like the Northern Hemisphere and the Southern Hemisphere using the 2-dimensional manifold using at least two charts. The 2-dimensional manifold which used at least four charts can express the front face of the anchor ring similarly. If the circle which has a node from R3 is removed, it will become an example of a three-dimensions manifold.

[0026] O By using differentiable mapping and a singular point chart, numeric representation of the map to a n-dimensional manifold from a p-dimensional manifold can be carried out as a map to each partition of Rn from each partition of Rp (every partition). About these maps, differentiability is verifiable. The map is Ck class if the element is continuously differentiable k times.
[0027] A height function is defined on a local coordinates system here. A height function is a function which returns the height (z-coordinate in the three-dimensions space where the body is embedded etc.) of the given point. The Jacobian matrix of height function h:R2 ->R is [0028].
[Equation 1]

It is come out and given. A Jacobian matrix is calculable about each point, and the maximum of the rank is the smaller one [p / n and]. The point that the rank of a Jacobian matrix is equal to this maximum is called a "regular point", and the other point is called "the singular point (singular point)" or "the critical point (critical point)." For example, there are a summit point (peak), the saddle point (saddle point), and a bottom of thread point (pit) in the singular point about a height function. If another way of saying is adopted, the singular point will be a point that a Jacobian matrix serves as the zero vector, and a normal vector will turn to the same direction as the height direction in the singular point.
[0029] O About the map (it is called "the function on a manifold" below) to R from the Hesse matrix, and characteristic the manifold of n-dimensional one, when all the values of the partial differential in a certain point are 0, the point turns into the critical point. The above-mentioned function is approximated in such a point by the quadratic form based on a secondary partial differential. This matrix display is called the Hesse matrix and that element is described as follows.
[0030]
[Equation 2]

The number of the negative characteristic value of the Hesse matrix in the singular point is called
the characteristic (index) of the singular point. A characteristic is equal to the number of the minus
signs in abbreviation-ed format as it is shown in below-mentioned drawing 1 . That is, the characteristic of a summit is [1 and the bottom of thread point of 2 and the saddle point] 0. In the
case of the anchor ring, like below-mentioned drawing 3 (a) - (c), the critical points of characteristics 2, 1, and 0 are one piece, two pieces, and one piece, respectively.
[0031] When the rank of the Hesse matrix in the critical point is n, the singular point is not
degenerating, namely, is called "nondegenerate." With the 2nd class function of any C, it can
approximate with a Morse function. A Morse function means a function which does not have
degeneracy of the critical point. Therefore, as far as the critical point of a Morse function should
be isolated and a compact manifold is concerned, as for the critical point, only a finite individual
exists.
[0032] O According to the mold Morse theory of a homotopy, the Morse function on a manifold
and its manifold is given, and if the method of **** of the characteristic of the singular point of the
function becomes clear, the phase space same homotopy type as the manifold can be built as a cell
complex (cell complex) by performing a series of operations corresponding to each singular point.

[0033] About the real number of the arbitration showing height, a cel (cell) gives the model about
the portion of a manifold which consists of a point below the height which the real number shows.
When R is scanned up and down, although the phase of a cel does not change, during the two
continuous singular points, it can complete a ** cel by connecting the "k-dimensional cel" to the
cel before it, whenever it crosses the singular point. k is the characteristic of the crossed singular
point here. If it says simply, an objective form can be restored by sticking a thing called a cel with
the same dimension as the characteristic of the critical point.
[0034] Drawing 1 is drawing showing the relation of the body encoded by the characteristic of the
singular point, a k-dimensional cel, and it. Here, the anchor ring is mentioned as a body. When the

height observed as shown in this drawing crosses height including the critical point, the phase constituted by the point below the height changes. This change is the same as connecting a k-dimensional cel so that it may mention later, if it sees in phase. As shown in this drawing, the form where the 2-dimensional cel (k= 2) turned down the bowl, and a single dimension cel (k= 1) can express a form like a string, and a zero-order former cel (k= 0) with one point. The form of the body of a basis is acquired by deforming like clay work, after connecting those cels. In the case of the anchor ring, one piece is connected for a 2-dimensional cel, two pieces and one zero-order former cel are connected for a single dimension cel, and it is obtained.

[0035] here -- being careful -- it is being unable to describe a cel thoroughly only in the array of a characteristic. Drawing 2 (a) - (c) shows 3 sets of curved surfaces with the array of the characteristic of Morse with the same each. Thus, a cel cannot be thoroughly decided only in the array of a characteristic. Therefore, when connecting the cel, it must know whether which connected component (substance which became independent, respectively) is related.

[0036] REBU (G. Reeb) advocated the graph obtained from a manifold as phase quotient space. A REBU graph is obtained by the correlation of the singular point being shown, expressing a body front face with a contour line, and expressing the connected component of each contour line as one point. REBU drew this graph in the manifold (suppose that it is compact) by carrying out eye DIN tee FAI of all the points included in the connected component same as a cross section which has the same value and corresponds under a Morse function. That is, the connected component of the portion of the manifold which exists between flat surfaces including the two critical points is expressed as an edge (side) of a graph, and each singular point corresponds to each top-most vertices of a graph. A REBU graph can be called graph which shows an objective frame.

[0037] Drawing 3 (a) - (c) is drawing showing the relation between the anchor ring and its REBU graph. In drawing 3 (a), the anchor ring of a basis and drawing 3 (b) show the cross section, and drawing 3 (c) shows the REBU graph. In drawing 3 (b), the portion of the circle which do not exist

and overlap in the same flat surface is equivalent to two separate edges in (c). Since this REBU graph is extremely excellent in power of expression as an icon, it uses this graph for an icon display if needed henceforth.

[0038] (3) a theoretical limit -- when the Morse theory is used by the method classic in this way, the thing which can discover the phase-property which is inherent in a manifold and which is not boiled too much is important. Only in the array of a characteristic, a manifold cannot encode the condition of being embedded in space. For example, it cannot know whether a node is in the anchor ring embedded in space. It is for two different configurations to result at the same singular point as shown in drawing 2 (b). Simple coding by the Morse theory cannot show whether there is any connection as similarly shown in drawing 2 (c).

[0039] (4) the escape of coding based on the Morse theory -- here, restrict the object of an argument to the front face of the compact 2-dimensional manifold of the 2nd class of C (C2 embedded in three-dimensions space). The Morse function on the curved surface which this system uses is guided from the height function in space. In fact, since degeneracy of the critical point can be abolished if C2 curved surface is rotated slightly, the height function can be made into a Morse function.

[0040] According to the Morse theory, the phase of a cross section does not change between two critical level (height of the flat surface where the critical point is included). From this, the curved surface between two critical level can be modeled using many cylinders with which knee condition differs. A system is built using this data.

[0041] Since the cross section without the singular point consists of circles embedded at the flat surface, structural coding is needed in order to display the inclusion relation of border lines. That is, it is coding which carries out grouping of two or more circles contained in the same circle.

[0042] This system proposes extended coding which adds new information to Morse's characteristic other than the information (namely, connection condition between each top-most vertices) acquired from a REBU graph. That is, this information is the information about to what

kind of sense how, are exchanged and two or more cylinders between two continuous critical values are connected.

[0043] (5) Explain the outline of the example coding system of a coding system. In this system, a curved surface is expressed by connecting the k-dimensional cel one after another to the curved surface. And the layered structure of the border line in each cross section is pursued. Here, the operator which shows connection of a cel is introduced and a curved surface is encoded using these operators. By expressing the cel connected by the operator by the icon, an understanding of the structure of the curved surface set as the object of coding is made easy. The result of coding obtained has the greatest feature of this coding system in guaranteeing the rightness of a phase.

[0044] O The expression method of the layered structure of a parentage and a border-line border line is explained. Here, the tree structure is used. First, when a certain border line includes another border line, the former is called the latter parent border line and the latter is called the former child border line. Drawing 4 (a) and (b) are the parentage of a border line, and drawing showing the expression by the tree structure. A parentage can be made into nesting structure like drawing 4 (a). The following and a border line are an eye most. #1 It is shown. #1 ** #2 A parent border line and #2 #4 It is a parent border line. #1 ** #7 The border line which does not have a parent border line like is a "virtual border line. It is expressed as the child border line of #0." Therefore, #0 It comes to the top-most vertices of the tree structure.

[0045] In order to show the parents of a certain border line, it arranges. Parent#[] A definition is given. for example, -- Parent#[1] =0 it is . On the other hand, it is the child border line of a certain border line. Children It is listed by the array to say and the pointer to the array is attached. For example #3 It is a child border line. #5 It reaches. #6 It is described as follows.

[0046]

Children[3] **[1] =5 and Children[3] **[2] =6 -- border lines with the same parent border line are called a twin border line. In the case of drawing 4 (a), it is #2. #3 It is a twin border line. The

child of a grandfather border line and a child border line is called a grandchild border line for the
parents of a parent border line. Moreover, the border line with which a body exists in the interior
is called a solid border line, and the border line not existing is called a hollow border line. In the
case of drawing 4 (a), it is #1, #4, #5, #6, and #7. A solid border line and #2 It reaches. #3 It is a
hollow border line.
[0047] O The operator of four operators for connecting a cel, Put_e0, Put_e1_merge, Put_e1_divide, and Put_e2 A definition is given. These are the operators which stick a cel.
Hereafter, a k-dimensional cel is displayed as ek. An objective configuration progresses towards
the bottom of thread from a summit. Processing is ended when it became impossible to connect a
cel more than it. In order to show the condition of the curved surface which it is going to constitute
with a operator, the border line in each cross section is used. Drawing 5 shows how to constitute
the anchor ring using these operators. The function of a operator is explained using this drawing
below.
[0048] 1. In order to generate e2 as shown in the top of this drawing Put_e2 (0) is performed. This
parameter "0" #1 #0 Being generated inside is shown. The cross section of this cel is shown in the
part of "a cross-section display" of this drawing. drawing -- like -- Put_e2 It has the function
which generates a border line on the flat surface of a cross section. border line generated by
Put_e2 (0) in order to give the numeric character of the order of generation to the border line
generated by the operator #1 it is .
[0049] The condition of the newly generated border line is always "enabling" as initial value.
Enabling shows the condition that connecting a cel to the border line is allowed. The icon display
of e2 is shown under this drawing "an icon."
[0050] 2. Continue and stick e1 to e2 by Put_e1_divide (1, nil, inside). Newly generated border
line #2 It carries out. Parameter "inside" #2 Parent#[1] =0 Being generated as a child border line
is shown. The second parameter shows the list of child border lines which should be referred to.

Here, the 2nd parameter is "nil" and the actuation and the concrete target to a child border line do not have deletion of a child border line.

[0051] 3. Next, use Put_e1_merge (1 2), stick e1 [another], and it is #1. #2 It merges. This operator merges into a 1st parameter side the border line shown with the 1st and the 2nd parameter. Since the border line which the 2nd parameter shows by merge disappears, it is deleted from the list of child border lines which the parent border line has [it]. Simultaneously, the condition of the border line is changed into "disabling" from "enabling." Therefore, a cel is not newly connectable with this border line.

[0052] 4. At last e0 is stuck using Put_e0 (1), and it is #1. It closes. #1 ****** is changed into disabling from enabling. The icon is reflecting this modification. When a cel e0 is connected to a certain border line, all the child border lines that the border line has must be disabled beforehand.

Since the border line which remains in the state of enabling is lost with the above procedure, attachment of the cel by the operator is completed.

[0053] Drawing 6 -8 are drawing showing the example of programming of a operator in false pascal code. drawing -- setting -- Max_children Max_contour_number It is a positive, sufficiently big integer and is used only for memory allocation.

[0054] It sets to drawing 6 and is Number_of_children. The number of the child border lines of each border line, and Most_recently_created# The number of the border line generated most recently, and Contour_status It is shown whether each border line is enabling or it is disabling.

Children The list of child border lines of a certain border line is held. Child_list ** -- it is a pointer to the array to say. Child_list Termination is a constant. End_of_list It is shown. These variables are initialized in the following procedures.

[0055]

Thereby, it enables a virtual border line. Following create_new_contour A new border line is made and it is Most_recently_created#. It is made to increase and the condition is initialized.

[0056]

procedure create_new_contour; begin
most_recently_created#:=most_recently_created#+1;
contour_status[most_recently_created#]:=enabled; In end drawing 7 , in order to use it behind, two
procedures and three functions are defined. Add_listed_children It is the 2nd parameter. clist The
border line currently listed is added to the list of child border lines (children [n] **) of the 1st
parameter. Remove_listed_children It is the 2nd parameter from the list of child border lines
(children [n] **) of the 1st parameter. clist The border line currently listed is deleted. These
procedures are Number_of_children again. It reaches. The array of Parent# is updated.
[0057] On the other hand, it is a function. Add_children (n, clist) clist All border lines #n "Truth"
is returned when it is a child border line. A "false" is returned when other. Function in_list (n,
clist) clist #n When contained, "truth" is returned, and a "false" is returned when other. Function
List_containing_only (n) is 2 procedures and Add_listed_children. It reaches.
Remove_Listed_children It defines in order to make the list which receives and contains only one
border line which should be given.
[0058] By these, they are four operators. Put_e2, Put_e0, and Put_e1_divide It reaches.
Put_e1_merge can be defined. These are shown in drawing 8 .
1. Put_e2 (n) #n A border line new as a child border line is generated.
2. By sticking e0, Put_e0 (n) is #n. It deletes. Here, All_successors_disabled (n, contour_number)
is #n. It restricts to the time when all whose child border lines are disabling, and "truth" is returned.
[0059] 3. Put_e1_divide (n, clist, inside) is #n. It divides and a new border line is made. Clist The
border line currently listed turns into a child border line of the border line newly generated. them
-- #r=#n or -- #r=parent# [n] the time of one side being realized -- #r It is deleted from the list of
child border lines. (It is dependent on whether this was which child border line of #n or parent#
[n]) . Only these two cases are allowed.
[0060] 4. Put_e1_merge (c1, c2) #c2 #c1 It merges. # c2 It is deleted from the list of child border
lines of Parent# [c2]. # c2 All child border lines Parent# [c1] -- or -- #c1 It becomes a child
border line (it is dependent on whether #c1 is the parent border line of #c2, or it is a twin border
line the any they are). Only these two cases are allowed.

[0061] In order to understand easily the structure of the curved surface encoded by these operators,
the visual display of the cel which constitutes the REBU graph of a curved surface is proposed.
The icon shown in drawing 9 expresses the cel, respectively. Lamination of a cel is performed by
contacting the nuchal plane where one cel is even, and the base where the cel of another side is
even. A black icon is used for a white icon and a solid border line at a hollow border line. Two or
more icons exist about e1.
[0062] Drawing 10 is drawing showing the lamination of a cel, and as shown in this drawing, the
icon of a child border line is drawn inside the icon of the parent border line. The icon of the
mirror image about a perpendicular shaft is also accepted.
[0063] The feature of an icon is in the point of maintaining the structure of a border line where it is
stuck. For example, as shown in the upper half of drawing 10 , when e1 is connected to a cel, the
structure of the parentage of a cel where an icon will be connected is maintained.
[0064] As shown in the lower half of drawing 10 , a dummy icon is inserted when the height of a
cel needs to be adjusted. Since a REBU graph is not planar graph, it can also make a cel cross
using a dummy icon. Consequently, it becomes possible to connect with the cel which left e1.
When e1 exchanges cels, the internal structure is also exchanged simultaneously. In order to hold
the structure of a hierarchical border line, a dummy icon cannot cross the boundary of the parent
border line of a border line on which it is stuck, and cannot invade into other border lines, either.
From this reason, a border line exchangeable using a dummy icon is restricted to a twin border
line.
[0065] As the above conclusion, the example of coding of the body which used the operator for
drawing 11 -13 is shown. What showed the REBU graph of the target body [drawing 11] by the
icon, the thing drawing 12 indicated the border line of the cross section of the body to be, and
drawing 13 are the operators for constituting the body.
[0066] [2] Constitute an objective curved surface based on the coded data obtained by the method

of the generation above-mentioned of the curved surface as a locus of the configuration (1) homotopy of the curved surface from the sign using a operator. Among cross sections including the critical point, the phase of a border line does not change as already stated. When it scans from top-most vertices to a base, the configuration of a border line changes. Deformation of this border line can be well expressed using a homotopy. A homotopy changes a certain function into other functions. In the following explanation, all border lines are expressed by the form function and suppose that deformation is expressed by the homotopy. The definition of a homotopy is as follows.

[0067] [Definition] When X and Y are phase space, a map called f and g:X->Y is considered.
Here, when map F:XxI->Y of which F(x 0) =f(x) F(x 1) =g (x) consists exists to all the points x that become x**X, "f and g are homotopics" is said. It is I=[0, 1] **R here. Moreover, Map F is called "the homotopy from f to g" at this time. When F is defined by F(x t) =(1-t) f(x)+tg(x), this is called a straight-line homotopy. Homotopy deformation of a border line is shown in drawing 14 .
As for the border line of a form function f and the one side bottom, the top border line is expressed by g in this drawing. A curved surface is generated as a locus of the homotopy F from f to g.

[0068] (2) The operator for generating the curved surface of element drawing 14 for implementing a operator can be described as what transforms a border line by the homotopy.

[0069] 1. The following four main elements which constitute a operator are drawn on element drawing 15 which constitutes a operator.

[0070]
(i) f:I->R3 (ii) which gives the configuration of the upper border line g:I->R3 Homotopy from F:f which gives the configuration of a lower border line (iii) to g (iv) The following form functions are prepared as difference 2. form functions f and g of the height of h:2 border lines.

[0071]
(i) Point : Constant function which always gives the location of the fixed point (ii) Circle : The polygon which gives the configuration of a circle (iii): (iv) which gives the polygonal

configuration of connecting the top-most vertices of arbitration Bezier: It is described by the
degree type by the n-dimensional Bezier curve.
[0072]
[Equation 3]

This function is specified by the set (with sequence) of n points called control point Pi**R3. This
control point is correctable with a user. Here, Bni (t) is the basis function of ** RUNSHUTAIN,
and is defined by the degree type.
[0073]
[Equation 4]

(v) -- NURBS (Non Uniform Rational B-Spline) curvilinear: -- the control point of this curve is
also defined by the user. A NURBS curve is defined by the following formula.
[0074]
[Equation 5]

Wi is the weight of each control point here. nickel and k (t) show the value of each partition of the
following polynomial called B spline basis function (k-1). This is defined by the degree type.
[0075]
[Equation 6]

NURBS is used by very many CAD systems. NURBS can express the quadratic surface to
accuracy, and has a local approximation property. That is, since the configuration of a curved
surface is affected only by the neighborhood of a point when a control point or the weight relevant
to it changes, it is fit for partial deformation actuation.
[0076] 3. The following functions are introduced as homotopy F one side and a homotopy F. These
functions output the border line of a cross section.
[0077] (i) linearity: -- straight-line homotopy (ii) quadrant form: -- [Equation 7]

Parabola: (iii) F(x t) =(1-t2) f(x)+t2g(x) and (iv) Car JINARU spline: A car JINARU spline

carries out interpolation interpolation of the border line of the top and the bottom. The decision of
a parameter is automatable by using the known toroidal graph which shows the corresponding
points between border lines.
[0078] (v) -- guy DIN GUKABU: -- a border line can be transformed by moving the point on a
border line along with guy DIN GUKABU. Two or more guy DIN GUKABU can be attached to a
border line. When a border line is expressed with a Bezier curve or a NURBS curve, guy DIN
GUKABU is attached to a control point, and a motion of a control point opts for deformation. A
motion of the control point where guy DIN GUKABU is not attached is calculable using guy DIN
GUKABU of an adjoining control point.
[0079] Drawing 16 shows signs that the upper border line is gradually transformed into a lower
border line, when a user attaches guy DIN GUKABU. In any case, a patch can be applied for
between the border lines obtained as a result using a car JINARU spline, and it can generate a
curved surface.
[0080] 4. The form function of the border line for the form function operator of the border line for
a operator is given as follows.
[0081] (i) Put_e2f:point g: A user specifies (default: circle).
F: A user specifies (default: quadrant form).
(ii) Put_e0 f:e0 The form-function g:point F of the border line attached: A user specifies (default:
quadrant form).
(iii) Path c:[0, 1] ->R3 of Put_e1_divide and Put_e1_mergee1 must be decided. It is Path c when it
actually implements. c (0) and c (1/2) It reaches. c (1) It is specified by the location. a path --
having to be smooth -- moreover -- c (1/2) The vector of the tangent which can be set must be
parallel to xy flat surface. Therefore, c (1/2) The saddle point of the generated curved surface
comes. c (1/2) An initial position is [0082].
[Equation 8]

It comes out. It is here and is [0083].
[Equation 9]

It comes out. Initial value of a path c (0) c (1) It is the arc of the ellipse to connect and is
[0084]
about 0 <=t<=1/2.
[Equation 10]

It is come out and given and, on the other hand, is [Equation 11] about 1 / 2<=t<=1.

It is come out and given. The projection to xy flat surface of the initial value of this path is c (0). It
reaches. c (1) It becomes the segment to connect. this -- c (t) In a formula, if the portion of the root
(1/square) is transposed to (1-x2), the path of a parabola can also be obtained. Put_e1_divide It
reaches. Put_e1_merge The element is as follows.
[0085] - Form function c:e1of border line with which Put_e1_dividef:e1 is attached c (0), c(1):
c(0) =f (s1), c (1) =f (s2) s1, g1, g2 which are specified by s2** [0, 1] : [The path f1 of -Put_e1_mergec:e1 obtained by dividing a border line along Path c, form function / of the border
line with which f2:e1 is attached / c (0),] c(1): c(0) =f1 (s1) and c(1) = f2 (s2) s1, g specified by
s2** [0, 1]: Put_e1_divide obtained by merging a border line along Path c The deformation to
depend By using the path of e1 as guy DIN GUKABU, it is carried out by transforming a border
line. Namely, [0086] - It is F(s1, t) = c(t/2) -F(s2, t) = c (1-t/2). On the other hand, it is Put_e1_merge. Deformation is acquired by the degree type.
[0087] - More than F1(s1, t) = c(t/2) -F2(s2, t) = c (1-t/2) is premise technology. It will be as
follows if this premise technology is packed focusing on relation with the gestalt of operation.
[0088] According to the Morse theory, the phase space same based on the information on the
singular point and a characteristic homotopy type as the object of the basis which is a manifold can
be built by the cell (cel) about [1]. If mathematical strictness is disregarded and said, the three-dimensions configuration of the object of a basis is notionally reproducible from the singular
point, its characteristic, and list direction of the singular point with the Morse theory very little
singular point related information and here. However, in the Morse theory, the cel is connected
how concretely, or [that is,] the connected component of a cel is not known.

[0089] A REBU graph is useful to the dissolution of the trouble of such the Morse theory. A REBU graph just shows connection of a cel and the connection relation during the singular point (i.e., between nodes) understands it from the side of an edge, i.e., a graph. The three-dimensions configuration of an object becomes clear by combining the Morse theory and a REBU graph. The existing polygon data in which the configuration of an object is shown is more specifically acquired, the information relevant to the singular point of the Morse function set up to the data is extracted, and the initial entry during the singular point is acquired. The configuration of the object of a basis can be caught for the information only on that in principle.

[0090] It is mainly the structure of an object, or the frame, i.e., global topology, which is reproducible with the Morse theory and a REBU graph. Therefore, it will depend for a more exact configuration on additional geometric information. Therefore, the border-line information on an object is acquired.

[0091] The decisive difference in the gestalt of premise technology and this operation is in the Morse function to adopt. That is, with premise technology, the height function, i.e., the function which returns the z-coordinate of a point currently observed, was considered as a Morse function. Graph distance is adopted as a Morse function with the gestalt of this operation. This function returns the minimum number of polygon edges which results to the top-most vertices currently observed from those top-most vertices, when the top-most vertices used as the base are set to the polygon object of a basis. Naturally a REBU graph can also create the basis of this Morse function, and that process can be automated.

[0092] After the frame of an object is described by [1] about [2], how to stick a curved surface on an object is shown. Although the concept of a homotopy type appeared in [1], the concept of the homotopy of a function appears in [2].

[0093] According to [1] and [2], if continuation deformation of between critical cross sections is carried out by the homotopy, the curved surface of an object is reproducible. Since the phase of a border line will change if a critical cross section is crossed, a curved surface is expressed by

homotopy even with another it. that is, the need which can be expressed with a continuous function like a homotopy -- the cross section which realizes a sufficient number of division is a critical cross section.

[0094] A critical cross section is equivalent to an edge between critical cross sections at the node of a REBU graph, respectively. The node corresponding to the cel of e2 and e0 is equivalent to the cel of a 2-dimensional open disk and an inphase, i.e., a 2-dimensional cel, on topology. However, although the cel of e2 and e0 was the singular point without degeneracy with premise technology, the unique side which degenerated is pointed out with the gestalt of operation. However, degeneracy is avoidable by establishing the offset on the unique side.

[0095] In an actual object, since the curved surface of a cylinder and an inphase is in the surroundings of it for every edge of a REBU graph, each edge is equivalent to one ANYURASU (about that cylindrical phase geometric name) on topology. Therefore, with the gestalt of operation, the object will be decomposed into a 2-dimensional cel and the configuration element containing ANYURASU by acquiring the REBU graph of an object. If base top-most vertices are decided to an object, since it is decided that a REBU graph will be a meaning, it can decompose any objects into a configuration element constantly and mechanically. This is a profit using premise technology. In addition, since all of a 2-dimensional cel and ANYURASU become the form of a triangle strip, they are easy to encode so that it may mention later.

[0096] Unlike premise technology, the gestalt of operation divides coding of an object into two steps, coding of the initial entry between polygon top-most vertices, and coding of the geometric information on polygon top-most vertices. This is for the gestalt of this operation to aim at compression of polygon data to premise technology aiming at generation of a smooth surface.

Graph distance was adopted as a Morse function, because it was considered to be a function with high compatibility by polygon data.

[0097] [the gestalt of operation] -- the concept used with the gestalt of operation and the outline of processing are explained first.

Configuration element drawing 17 shows the configuration element in the gestalt of operation.

Here, the three-dimensions object of a H character mold is illustrated.
[0098] The cross-section border line of the closed surface M which is an object is defined as the connection equivalent line of continuous function f:M->R defined on the curved surface. With the gestalt of operation, the graph distance from the base top-most vertices made into this function f is taken. The first configuration element is a border line expressed with the graph structure named c graph. c graph consists of the node and edge it writes c graph and the c edge [edge] 14 (c is the mind of an outline contour), respectively. All the graph distance of the top-most vertices on single c graph is equal. However, for intelligibility, this drawing changes the graph distance of an object in the height direction, and shows it.
[0099] c graph may consist only of a c node 10 of one point, and the c node 10 serves as the summit point or bottom of thread point which is the singular point of Morse function f then. When c graph is one loop-like, I form the 1c node 10 for convenience on the loop, and think that one c edge 14 which makes the c node 10 an endpoint exists. That is, when c graph is a loop, this has the c node 10 and one c edge 14 at a time in principle, respectively.
[0100] When c graph is the form of "8", one c node 10 of the singular point which is the saddle point exists in the crossing point. Two loops correspond to one c edge 14, respectively.
[0101] Thus, by giving a definition, the gestalt of operation can guarantee the justification of the closed surface in which orientation is possible. That is, an equation is defined for the method of an oiler as the following like a boundary representation method.
[0102] # c node-#(c edge)+#(2-dimensional cel) = -- # expresses the number of each elements two to 2 g here. Moreover, g expresses the handle of a closed surface, i.e., the number of holes. In the case of drawing 17 , a top type is [0103]. It is set to 6-5+1=2-0, and, surely is realized. By this formula, the coding equipment of the gestalt of operation has collateralized the rightness of that an object is a closed surface and its coding.
[0104] A configuration element contains two more element, ANYURASU 16, and the 2-dimensional cel 18. ANYURASU is as in phase as a cylinder including two different c graphs or

the part of those on the boundary. On the other hand, the 2-dimensional cel is as in phase as an open disk including the one free borderline which consists of one c graph or its part.

[0105] Like the after-mentioned, a 2-dimensional cel and ANYURASU are extracted from the triangle mesh of an object based on graph distance so that the form of a triangle strip may be taken. A triangle strip says the train of the linear triangle started by one direction where the initial entry is expressed with the stream of "0" or "1" as it is shown in drawing 18 . The bit stream by this "0" and "1" is called the MACHINGU pattern. In the case of this drawing, a MACHINGU pattern is "01001011."

[0106] Graph distance becomes settled to each top-most vertices. The graph distance of a certain top-most vertices is the number of the edges of the shortest path in which it results [from base top-most vertices] to the top-most vertices. This is calculable using the algorithm of known Dijkstra. An important thing is that the graph distance of a certain top-most vertices has only the graph distance of top-most vertices and the difference of 0 or 1 which adjoin it here.

[0107] Although a fundamental configuration element is assembled above, with the gestalt of operation, opening ANYURASU is defined as the ability also treating an opening mesh. An opening mesh means a mesh with an edge to which a triangle exists only in one side of a certain edge. Opening ANYURASU takes the form of the triangle strip which has not been closed. The first edge which has not been closed and the last edge are opening edges. Opening ANYURASU is a concept contrasted with above-mentioned ANYURASU which ends closed exactly, i.e., ANYURASU of normal. In topology, with a disk, although opening ANYURASU is in phase, it has two different outline graphs (or the part) as the borderline like ANYURASU of normal. What is necessary is just to follow ANYURASU from a certain initiation polygon edge to an one direction, in order for ANYURASU to check normal or opening. If it returns to a start point, ANYURASU is regular, otherwise, open. In addition, opening ANYURASU is effective also in coding of a non-manifold like the after-mentioned. [0108] The first step which extracts the construction

configuration element of a configuration element is to clarify to any of each configuration element three square shapes each, the edge, and top-most vertices which are included in a triangular mesh are classified, and it belongs. A triangle is contained in either a 2-dimensional cel or ANYURASU. If all of three triangular top-most vertices have the same graph distance, this triangle exists on a 2-dimensional cel. When other, it is on ANYURASU.

[0109] An edge is classified using the following steps.

Step 1: If the graph distance of the top-most vertices of the ends of an edge differs, this edge exists on ANYURASU. When that is not right, it progresses to step 2.

Step 2: If the edge of ANYURASU exists in four adjoining wing DOEJJI, the edge exists on c graph. When that is not right, it progresses to step 3.

Step 3: When a triangle with two edges already classified the 2-dimensional cel top among the triangles which adjoin an edge is also one, the edge exists on c graph. When that is not right, it is on a 2-dimensional cel.

[0110] Top-most vertices are classified into either the top-most vertices on c edge, or c node. If the number of c edges included in the top-most vertices is 2, the top-most vertices are the usual top-most vertices on c edge. When that is not right, it serves as c node like the crossing point of the character of "8" described previously.

[0111] Step 3 is conditions required since two dimensions become a triangle strip. Supposing all of three edges which exist about a certain triangle are on a 2-dimensional cel, a 2-dimensional cel branches with the triangle, and is no longer a triangle strip.

[0112] Once the element of a mesh is classified, ANYURASU, a 2-dimensional cel, and c graph will be built by unifying those triangles, an edge, and top-most vertices, respectively. If it is on c graph, it is classified and the edge each other connected constitutes one c graph. The triangle according to which it was classified when it was in ANYURASU, and its contiguity triangle are unified by one ANYURASU when sharing an edge within the ANYURASU. This processing is performed repeatedly. As shown in drawing 19 and drawing 20 , ANYURASU and the 2-dimensional cel which were built by this method always take the form of a triangle strip.

[0113] c graph can be decomposed into c node and c edge by using the classification of the top-most vertices and the edge which were defined previously. In addition, it can have big effect on the below-mentioned compressibility by whether which top-most vertices of a polygon mesh are appointed at base top-most vertices, and the definition of Function f. A user may specify base top-most vertices and you may set them automatically. There is selection based on geometric information, such as choosing top-most vertices where the coordinate value of a a certain direction of z, for example, the direction, becomes max, and the spinode of a polygon mesh as an example of automatic setting. Moreover, its attention may be paid to global topology, such as top-most vertices which branching produces. Anyway, the graph distance in base top-most vertices is 0.

[0114] Drawing 21 shows the configuration element obtained when only one base top-most vertices 20 were specified. On the other hand, drawing 22 shows the configuration element obtained as a result of specifying several base top-most vertices 20 first. All have chosen the anchor ring (doughnut) as an object.

[0115] A black line expresses c graph among drawing. In this example, when two or more base top-most vertices are specified, the compressibility of data has been improved about 20% as a result. By choosing the continuous function for which it was suitable with the structure of a polygon mesh, it is because the below-mentioned prediction processing for compressing geometric information is improved.

[0116] After this [compression] without the loss of an initial entry, the member variable of each configuration element is compressed by Huffman coding, and the MACHINGU pattern of a triangle strip, i.e., the initial entry of a polygon mesh, is encoded as a bit stream. Since the MACHINGU pattern of a basis can reappear thoroughly by decode processing in compression by this method, compression of loss loess is realized.

[0117] the loss of an initial entry -- there is another method about loess compression. The coding

method which describes the total number of a certain top-most vertices and another top-most vertices by which connection is carried out in predetermined order is indicated by Touma's and others "Triangle Mesh Compression" (Graphics Interface'98 Proceedings, pp.26-34, 1998).

[0118] Drawing 23 (a) - (t) shows the procedure of Touma's and others coding method. In these drawings, a thick continuous line is called an active list and the "interior" containing the already encoded edge and the "exterior" which is not encoded yet are separated. A dashed line shows the already encoded edge.

[0119] By this method, a polygon mesh is inputted first (drawing 23 (a)), dummy top-most vertices are introduced, and this is connected with all top-most vertices (drawing 23 (b)). The method of Touma is for assuming a closed surface. Next the first triangle is chosen and a mark is attached to the top-most vertices (it is only hereafter called a focus) used as a focus (drawing 23 (c)). The number of the top-most vertices connected to this focus describes this to be "add6" because of 6. A focus is left as it is and obtains "add7" counter clockwise paying attention to the next top-most vertices. "add4" is further obtained about the next top-most vertices by the same processing.

[0120] It continues, and focusing on a focus, it is counter clockwise and an active list is opened (drawing 23 (d)). "add4" is obtained about the top-most vertices which newly joined the active list. Similarly, "add8" (drawing 23 (e)), "add5" (drawing 23 (f)), and "add5" (drawing 23 (g)) are obtained. Coding about this focus is finished here.

[0121] A focus moves to an active list along with the circumference of an anti-clock (drawing 23 (h)), and obtains "add4" (drawing 23 (i)) and "add5" (drawing 23 (j)). Since the top-most vertices which should observe the next are already in an active list, a list is divided in two (drawing 23 (k)). Then, "split5" is obtained. split shows fission of a list. "5" is offset and points out the sequence counted about the edge which is not encoded yet by the clockwise rotation from a

focus. A stack is loaded with the smaller one among lists here, and processing of the larger one is continued. A focus is moved (drawing 23 (l)) and "add4" (drawing 23 (m)) and "add4" (drawing 23 (n)) are obtained. Processing finishes about the focus. "add dummy6" is obtained about dummy top-most vertices (drawing 23 (o)). Processing of the active list of the larger ones finishes, and the list of the smaller ones is taken out from a stack (drawing 23 (p)). "add4" is obtained about the new top-most vertices which appeared on the active list (drawing 23 (q)). Although all edges are encoded at this event, a focus moves (drawing 23 (r), drawing 23 (s)), and coding of the second list also finishes (drawing 23 (t)). By the above processing, the sign of this mesh is [0122]. It is set to add6, add7, add4, add4, add8, add5, add5, add4, add5, split5, add4, add4, add dummy6, and add4.

[0123] With the gestalt of operation, the method of this Touma may be used to a three square shape each strip. However, the another expression method concerning a design of this invention person may be adopted that it should correspond to a non-manifold. A non-manifold is an object which does not exist actually, when the triangle of three pieces shares one edge.

[0124] This method expresses the number of the surrounding triangles of a certain top-most vertices. Bases use an expression as shown in "3 (2, 4, 3)." As for this, in those with "three piece", and each set, a triangular set shows consisting of a triangle of "two pieces", a triangle of "four pieces", and a triangle of "three pieces" to the surroundings of a certain top-most vertices. In the case of a manifold, since there is always only surrounding triangle "one set" of a certain top-most vertices, by the method of Touma, it only must be set to "add6" etc.

[0125] Drawing 24 and 25 show a local curved-surface configuration for an object to serve as a non-manifold. drawing 24 -- like -- the projection 30 of a polygon -- the c edge 32 of the graph distance m -- said -- if it exists ranging over the triangle strip 40 formed with the c edge 34 of m+1, the top-most vertices 36 and 38 where projection 30 and the triangle strip 40 cross will

newly be defined as c node. Moreover, top-most vertices 36 and the triangle strip 40 divided into two fields s and t with the edge 42 between 38 are henceforth treated with opening ANYURASU.
In the case of this drawing, projection 30 self is also encoded as oven ANYURASU. As for both the ****** top-most vertices 36 and 38, a triangular set serves as those with "three piece", and a form of three (a, b, c) around at c node. Like drawing 25 , if the projection 30 of a polygon exists in the triangle strip 40 at parallel, new c node will not prepare. Also in this case, the sign about a certain top-most vertices 46 serves as a form of 3 (a, b, c).
[0126] By this method, the operator of Touma, i.e., add or split, does not use, but they use the operator based on a configuration element. concrete -- NEW_CNODE: -- OLD_CNODE: which builds new c node and moves a focus there -- NEW_CEDGE: which moves to c node which already exists -- OLD_CEDGE: which builds new c edge and moves there -- the operator of four moving to c edge which already exists is introduced. "NEW_CNODE" and "NEW_CEDGE" take the above-mentioned information on a triangle set as shown in "3 (2, 4, 3)" as an argument, and the operator of "OLD_CNODE" and "OLD_CEDGE" takes the index of the c node and c edge as an argument. As mentioned above, coding of a non-manifold is realized by this method.
[0127] A loss may be accepted also in coding of the compression joint information which allows the loss of an initial entry. With the gestalt of operation, in order to realize compression with a loss, toroidal graphic representation is used. A toroidal graph is used in order to be advocated by Fuchs and others by "Optimal Surface Reconstruction from Planar Contours" (Communications of the ACM, 20 (10), pp.693-702, and October 1977) and to generate the smoothest possible triangle mesh between two cross-section border lines by him.
[0128] Drawing 26 shows how to constitute the front face of ANYURASU or a 2-dimensional cel using a toroidal graph. this ANYURASU -- as that borderline -- the array (P0, P1, --, pm-1) of two top-most vertices -- and (Q0, Q1, --, Qn-1) it is constituted. Therefore, the size of a MACHINGU

pattern is m+n. In regular ANYURASU, P0=Pm-1 and Q0=Qn-1 are realized. It is assumed that the gestalt of operation has the edge of a polygon which connects P0, Q0 and Pm-1, and Qn-1 first, respectively. Therefore, a toroidal graph has the node of mxn. It can write ti and j [these nodes] (0 <=i<m, 0 <=j<n). Nodes ti and j show that the polygon edge from a certain top-most vertices Pi to another top-most vertices Qj exists here. In case it moves to the next node, the edge of two directions is possible for ti and j. That is, an edge (ti, j->ti +1, j) shows existence of the triangle constituted by (Pi, Pi+1, Qj). Moreover, an edge (ti, j->ti, j+1) shows existence of the triangle constituted by (Pi, Qj+1, Qj). The cost calculated based on a triangular area or the angle between adjoining fields can be assigned to each edge. For example, smaller cost is assigned to the way which has a big area among the triangles as a cover, and the one where the field in front of one and the angle to make are smaller.

[0129] the method of building a toroidal graph and building a MACHINGU pattern -- t -- it comes back to the problem which searches for the minimum cost path in the path of 0 and 0 to tm-1, and n-1. The minimum cost path is acquired by calculating the minimum cost of each node in following sequence (algorithm of Dijkstra).

[0130] t1, 0 ->t0, and 1-> -- t2, 0 ->t1, 1 ->t0, and 2-> ... ->tm-1, n-2 ->tm-2, n-1 ->tm-1, and n-1 -- in addition, Dr. Shinagawa who is one of this invention persons advocated extended toroidal graph algorithm in the paper introduced as premise technology. The method is [0131]. 1. the pair of the mutual nearest point about between the border lines of two upper and lower sides -- detecting -- 2. -- those pairs -- an edge -- an epilogue and 3. -- the other corresponding points interpolate and ask for between previous pairs Although Fuchs's and others method searched for the optimal path discretely, the method of Shinagawa can be called the continuous slab and the artificial wrinkling of the playback curved surface which often appears by Fuchs's and others method is mitigated. Naturally the gestalt of operation may use this extended toroidal graph.

[0132] The gestalt of compression implementation of geometric information is Taubin. The coordinate of top-most vertices is compressed based on "Geometric compression through topological surgery" (ACM Transactions on Graphics, 17 (2), pp.84-115, and April 1998). Usually, although a coordinate is expressed by the 32-bit floating decimal, since top-most vertices of a triangle mesh exist in the limited space, this expression has much futility. Then, the bounding box which encloses an object is introduced and the floating value fi of the coordinate of top-most vertices vi is rounded off to the fixed-length value ni. the fixed length rounded off -- bx, by, and bz are defined about x, y, and a z-coordinate, respectively. In order that bx, by, and bz might maintain the display precision of the mesh below the triangle of 100000 pieces as a result of an experiment, it was enough in 9-12 bits. The gestalt of operation introduces prediction, in order to compress further the value with which this fixed-length integer was rounded off. When encoding the value of top-most vertices, the error of the original value and the forecast calculated from the top-most vertices to precede is encoded by the Huffman coding which is entropy code modulation.

[0133] Although comparatively high compressibility was obtained also by the above method, the adaptability of triangle mesh structure is not taken into consideration yet. An accommodative mesh means a mesh which contains both a detailed triangle and a big triangle. In an accommodative mesh, when detailed structure is important, the rounding-off processing to a fixed-length integer is defined about the resolution of the fine structure. In this case, the error of the value predicted to be the original value is large about the location where a triangle is big, and the effectiveness of Huffman coding falls.

[0134] Drawing 27 shows the method of prediction of the geometric information over the accommodative mesh concerning a design of this invention person, and compression. In this drawing, ni-2, ni-1, the location where ni was rounded off and top-most-vertices vi-2, vi-1, and the actual location of vi became settled, respectively, the location of ni where pi was predicted by the linear from ni-2 and ni-1, and epsiloni are the errors of predicted pi and the below-mentioned

reference point nri.

[0135] The tolerance 60 of 2ai(s) is assigned to ni. That is, the encoded top-most vertices are allowed to take the any value of [ni-ai, ni+ai]. The large range ai is taken about the top-most vertices vi in the field where a triangle is big, and when it is reverse, it is taken small.

[0136] Compression of an accommodative mesh results in the following problems. That is, a reference point nri is determined that error epsiloni will make Huffman coding small as much as possible in tolerance 60, fulfilling the conditions of pi+epsiloni** [ni-ai, ni+ai]. In order to solve this technical problem, the number of steps si corresponding to ai is defined as follows.

[0137] si=2beta, however beta are the maximum integers which do not exceed log22ai. At this time, step si becomes a 2n (n is an integer) form, and serves as the maximum number of 2 or less ais. epsiloni is continuously calculated as follows using si.

[0138] epsiloni=eixsi however ei**N, and epsiloni** [ni-ai, ni+ai]

Such epsiloni becomes settled uniquely. epsiloni continues and is encoded by Huffman coding. It is equal to encoding in resolution which is different in each value for the number of steps si to be considered to be the resolution of a mesh here, respectively, and to carry out Huffman coding of the epsiloni based on two or more si(s). Consequently, compression of an efficient accommodative mesh is realized.

[0139] In compression of the coordinate of top-most vertices, the parameter ai about tolerance is calculated with the parameter alpha (adaptability parameter) specified by the minimum distance lmini and the user to normal vector normi of top-most vertices vi, and adjoining top-most vertices.

ai=(lmini/alpha) x|normixex|y|z| -- ai is calculated about x, y, and a z-coordinate here, respectively, and ex|y|z shows the unit vector of x, y, and the direction of z, respectively.

[0140] The adaptability parameter alpha is taken zero or more, and ai becomes so large that alpha becomes small. Compression becomes sensitive to the adaptability of a mesh and high compressibility realizes it, so that small alpha is taken. However, the quality of the encoded object tends to fall off. Normal vector normi prevents that top-most vertices shift in the direction of a normal. This is because the shift of the direction of a normal tends to be conspicuous, and this

becomes remarkable when a flat [especially a curved surface].
[0141] Although 8, 16, or more than it was enough as alpha as a result of the experiment, about the high mesh data of whenever [bump], about four were often more enough as alpha. The shift of the coordinate in a complicated mesh is because it is hard to be conspicuous from the shift in a comparatively smooth mesh. In case such a property of a mesh also determines the adaptability parameter alpha, it should take into consideration.
[0142] In addition, the above method is only an example of the technique of calculating ai. Moreover, the technique of this accommodative mesh is applicable to other geometric information, for example, a texture coordinate, a normal, a color, a reflection property, etc.
[0143] In order to encode the flow mesh of coding and decode and to control the quality and compressibility, the gestalt of operation uses the following input parameters.
[0144] v={--}: [vi1, vi2, and] The arrays bx and by of base top-most vertices, bit-length alpha by which bz:each coordinate was rounded off: Input-parameter v is used for coding of adaptability parameter topology. Although v often affects compressibility, it is sufficient if the top-most vertices of arbitration are usually specified. The parameters for geometric information coding are bx, by, bz, and alpha (> 0). A triangular mesh is encoded at the following steps.
[0145] Step 1: Pinpoint the creation base top-most vertices v of a configuration element, define the continuous function f about distance, and decompose an object into a configuration element.
Step 2: The compression coordinate value of geometric information is rounded off to bx, by, and bz, and perform compression using the adaptability prediction using Parameter alpha.
Step 3: Compress a MACHINGU pattern using the compression toroidal graph of topology.
[0146] It is important to compress geometric information before compression of a MACHINGU pattern. Because, it is for count of a toroidal graph to be dependent on the coordinate value of each top-most vertices. A toroidal graph is referred to only about the encoded value in the case of next decode. The geometric information on original cannot be referred to. Therefore, it is necessary to use the value which should be acquired as geometric information in the case of decode in the phase

of coding.
[0147] On the other hand, decode is the reverse of the procedure of coding. That is, 1. configuration element is decoded, the value of 2. geometry information is decoded, and three .
MACHINGU patterns are decoded.
[0148] When the polygon object of 20-900kB drawn in the ASCII format of VRML1.0 was processed in order to confirm the effect of the gestalt of operation, the image quality deterioration by compression was able to reduce data of a single figure to double figures in the range hardly seen. The time amount which coding and decode take was as high-speed as about 0.5 - 100 seconds generally. The experiment was conducted with the personal computer (266MHz of MMX Pentium) of the Linux base. The initial entry using a toroidal graph was compressible into 1 bit or less about the triangle piece. In the best case, it was also compressible to 0.2 bits or less about the triangle piece.
[0149] The gestalt of this operation does not need to wait for completion of decode for the display of an object, and indicates by sequential from the decoded place. Therefore, it is essentially suitable for the progressive display. The above is an outline.
[0150] Drawing 28 shows the configuration of the object coding equipment 100 concerning the gestalt of operation. The object acquisition section 104 inputs the polygon mesh of an object from the polygon object storage 102 or a network. The function setting-out section 106 sets up the function about graph distance on the curved surface which the inputted polygon mesh expresses. The function setting-out section 106 contains the zero definition part 108 which appoints the zero of a function, i.e., the base top-most vertices which are the criteria of graph distance, and the distance calculation section 110 which computes the graph distance from base top-most vertices to each top-most vertices of a polygon mesh.
[0151] The configuration element decomposition section 112 decomposes a polygon mesh to each configuration element based on said graph distance, and the coding section 114 encodes each configuration element done so and generated. Since it can consider that said function is the Morse

function explained with premise technology, the coded data of each configuration element includes the global structure or the topology of an object in the form of a REBU graph. The coding section 114 contains the geometric compression zone 116 which carries out compression coding of the geometric information on a polygon mesh, and the phase compression zone 118 which compresses the initial entry of polygon top-most vertices. The coded data output section 120 outputs the data obtained as a result of coding to the coded data storage 122 or a network.

[0152] On the other hand, drawing 29 shows the configuration of the object decode equipment 200 concerning the gestalt of operation. The coded data acquisition section 202 inputs the coded data of an object from the coded data storage 122 or a network. The configuration element extract section 204 extracts each configuration element of an object from the inputted coded data. The decode section 206 decodes each extracted configuration element. The decode section 206 contains the geometric decode section 208 reproducing the geometric information on a polygon mesh, and phase ******** 210 reproducing the initial entry of polygon top-most vertices. The decode data output section 212 outputs the data obtained as a result of decode to the decode data storage 214 or a network.

[0153] The details of a series of coding processings in the above configuration and decode processing are as having already stated. In addition, coding and decode of this invention can be recorded on various record media as a computer program, though natural, or they can be offered via various transmission media.

[0154] There is amelioration or deformation technology in object coding and the decode concerning the gestalt of operation. Although the case where the object was expressed in a polygon mesh was assumed with the gestalt of operation as the first modification, it is not restricted to this. For example, also in the case of others, this invention can be realized, when an object is expressed in a free sculptured surface, or it is expressed analytically and it is expressed by the boundary representation method or CSG (Constructive Solid Geometry). In that case, what is necessary is to

prepare a zero on the curved surface of an object, to set up a function, to generate a configuration element based on the function value, and just to encode.

[0155] As the second modification, although the zero was prepared on the curved surface of an object with the gestalt of operation, this may be prepared in the exterior or the interior of an object. In that case, it may replace with graph distance and another functions, such as distance from a zero to each point, may be adopted. In addition, you may realize by software, it realizes by hardware, and the potato of each technical element shown with the gestalt of operation is good.

[0156] As mentioned above, although the gestalt of operation was explained, the technical range of this invention is not limited to these publications. It is just going to be understood that various modification or amelioration can be added to the gestalt of these operations by this contractor.

That it may be contained in the technical range of this invention can also understand the gestalt which added such modification or amelioration from the publication of a claim.

[Translation done.]

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TECHNICAL FIELD

[The technical field to which invention belongs] This invention relates to object coding and decode technology. Especially this invention relates to the method and equipment which encode efficiently and decode the curved surface of the object described by the polygon mesh etc.

[Translation done.]

NOTICES *

PRIOR ART

[Description of the Prior Art] The spread of the Internet gave the opportunity to access information huge to people without special equipment. The electronic commerce using the Internet is going to progress quickly as this convenience is understood. The on-line shopping which exhibits a goods catalog and receives an order especially attracts attention as an intelligible use of electronic commerce.
[0003] The important requirements for on-line shopping are how to show goods attractively. Although the catalog by the photograph is an effective means, when a user wants to look at the goods from various directions, it is difficult to fill the want with a 2-dimensional photograph. Therefore, recently, the modeling of the goods is beforehand recarried out in the form of polygon data, and there is a motion considered so that a user can do actuation of amplification, a revolution, etc. freely in three dimensions.

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TECHNICAL PROBLEM

[Problem(s) to be Solved by the Invention] However, when goods are polygonized for this object, that amount of data becomes a problem. It is necessary to show especially goods delicately, therefore required polygon data may amount to several megabytes with one goods. Now, the sensation which winds freely the page of the conventional catalog which is paper data medium is not acquired. **** of on-line shopping is it to be [how a goods image can be transmitted and displayed quickly and] storable in the recording device to which a desired image and a desired three-dimensions configuration were restricted however.

[0005] This invention was made in view of such the actual condition, and the object is in offer of the technology which compresses and decodes the polygon mesh data of objects, such as goods.

[0006] In case another object of this invention compresses polygon data, it is in offer of the technology of giving a useful index to a next search etc. at the object, simultaneously.

[0007] Still more nearly another object of this invention has the decode time amount in short compression and offer of decode technology, when [at which the compressed polygon data is returned] decoding at the time that is,.

[0008] Still more nearly another object of this invention is in offer of the technology which compresses correctly a polygonization object with the constructional detail which cannot exist, and decodes it actually.

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MEANS

[Means for Solving the Problem] An object coding method of this invention includes a process which decomposes said curved surface to a configuration element which became independent, respectively, and a process which encodes said configuration element according to a process which acquires description of a curved surface of an object, a process which appoints a predetermined zero on said curved surface, and distance in which it results [from said zero] to each point on said curved surface. When described in a form where an object is a polygon mesh, said zeros may be predetermined base top-most vertices included in said polygon mesh, and said distance may be a graph distance in which it results [from said base top-most vertices] to each top-most vertices of said polygon mesh.
[0010] Graph distance becomes settled by the number of edges (side) which result for example, from base top-most vertices to a certain top-most vertices. A configuration element may also contain an outline graph of an object which is the set of an edge from which graph distance from base top-most vertices connects equal top-most vertices, and is acquired. Speaking roughly, each configuration element's serving as an independent field which slices an object and is obtained centering on base top-most vertices, for example.
[0011] If a concept of distance, especially graph distance is introduced, it will become comparatively easy to decompose an object to a configuration element uniformly. Moreover, since each configuration element is the independent field, it becomes comparatively easy [coding].

[0012] A configuration element may also include global topology of an object. Global topology is the meaning except local topology like an initial entry between polygon top-most vertices. There is structure graph or a frame graph obtained as global topology based on graph distance. Global topology is useful to a next search etc. as an index of an object.

[0013] Coding includes coding of local topology of coding of geometric information on an object, and an object. As local topology, there is an initial entry between polygon top-most vertices. Coding of topology may also include description to that effect, when a configuration expressed with said polygon mesh is a non-manifold. The number of sets of polygons, such as the number of fields gathering in top-most vertices used as a cause which a non-manifold produces in that case, and a triangle, may be described.

[0014] Coding of geometric information may be performed by being adapted for local magnitude of a polygon mesh. As an example, entropy code modulation of the difference of a prediction location and an actual location of a certain attention top-most vertices is carried out. Under the present circumstances, said difference is beforehand adjusted so that entropy code modulation may be optimized. Although geometric information is related with a coordinate, it includes information, such as others, top-most vertices, and a color of a field or a normal. In that case, what is necessary is just to carry out entropy code modulation of the difference of a forecast and an actual value of attention geometry information.

[0015] The object decode method of this invention can be used combining the object coding method of this invention, and includes the process which extracts the coding configuration element which was encoded after being decomposed according to distance in which it results to each point on the curved surface from a zero on a process which acquires coded data which describes a curved surface of an object, and said curved surface included in said coded data, and which becomes independent, respectively, and the process which decode said coding configuration element.

[0016] Object coding equipment of this invention materializes an above-mentioned object coding method, and contains a unit which decomposes said curved surface to a configuration element which became independent, respectively, and a unit which encodes said configuration element according to a unit which acquires description of a curved surface of an object, a unit which appoints a predetermined zero on said curved surface, and distance in which it results [from said zero] to each point on said curved surface.

[0017] It is characterized by equipping object decode equipment of this invention with the following. A unit which acquires coded data which materializes an above-mentioned object decode method, and can use combining the above-mentioned object coding equipment, and describes a curved surface of an object A unit which extracts a coding configuration element which was encoded after being decomposed according to distance in which it results to each point on the curved surface from a zero on said curved surface included in said coded data, and which becomes independent, respectively A unit which decodes said coding configuration element

[0018] Another gestalt of an object coding method of this invention includes a process which acquires an object, a process which defines a function about distance on a curved surface of said object, a process which acquires structure graph of said object based on a value of said function, and a process at which said structure graph encodes said object clearly so that it may be inherent in behind implicitly in the condition in which reconstruction or reference is possible. When an object is expressed in a polygon mesh, said function may output the number of polygon edges which result to each top-most vertices from predetermined base top-most vertices included in said polygon mesh. In addition, an outline of the above invention is not what enumerated all the features required for this invention, and though natural, a subcombination of these characterizing group can also be invented.

[0019]

[Embodiment of the Invention] Hereafter, this invention is explained through the gestalt of implementation of invention. However, not all the combination of the feature of the gestalt of the following operations that do not limit invention indicated by the claim and are explained in the gestalt of operation is necessarily indispensable for the solution means of invention.

[0020] The content of the paper which it faced understanding gestalt invention of operation and this invention person released previously

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DESCRIPTION OF DRAWINGS

[Brief Description of the Drawings]
[Drawing 1] It is drawing showing the relation of the body encoded by the characteristic of the
singular point, a k-dimensional cel, and it.
[Drawing 2] Drawing 2 (a) - (c) is drawing showing 3 sets of curved surfaces with the array of the
characteristic of Morse with the same each.
[Drawing 3] Drawing 3 (a) - (c) is drawing showing the relation between the anchor ring and its
REBU graph.
[Drawing 4] Drawing 4 (a) and (b) are the parentage of a border line, and drawing showing the
expression by the tree structure.
[Drawing 5] It is drawing showing how to encode the anchor ring using a operator.
[Drawing 6] It is drawing showing the example of programming of the operator in a false pascal
code.
[Drawing 7] It is drawing showing the example of programming of the operator in a false pascal
code.
[Drawing 8] It is drawing showing the example of programming of the operator in a false pascal
code.
[Drawing 9] Each is drawing showing the icon corresponding to a cel.
[Drawing 10] It is drawing showing the lamination of a cel.
[Drawing 11] It is drawing having shown the REBU graph of an object by the icon.
[Drawing 12] It is drawing showing the border line of the cross section of an object.
[Drawing 13] It is drawing showing the operator for constituting an object.
[Drawing 14] It is drawing showing homotopy deformation of a border line.
[Drawing 15] It is drawing showing the four main elements which constitute a operator.
[Drawing 16] It is drawing showing signs that the upper border line is gradually transformed into a

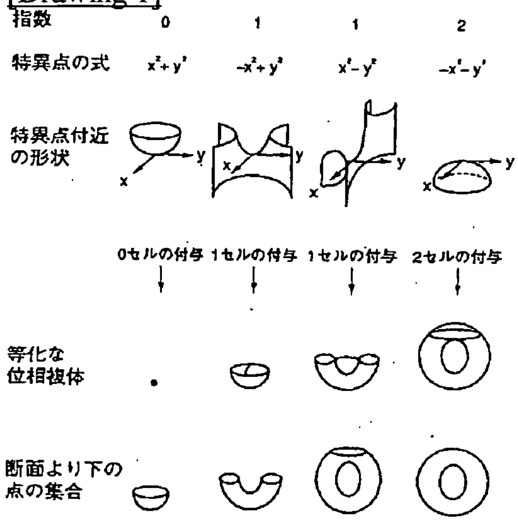
lower border line by the guy DINGU curve.
[Drawing 17] It is drawing showing the various configuration elements in the gestalt of operation.
[Drawing 18] It is drawing showing a MACHINGU pattern.
[Drawing 19] It is drawing showing the triangle strip of ANYURASU.
[Drawing 20] It is drawing showing the triangle strip of a 2-dimensional cel.
[Drawing 21] It is drawing showing the configuration element obtained when only one base top-most vertices are appointed.
[Drawing 22] It is drawing showing the configuration element obtained when much base top-most vertices are appointed.
[Drawing 23] Drawing 23 (a) - (t) is drawing showing the one method of encoding an initial entry.
[Drawing 24] It is drawing showing the example of a non-manifold object.
[Drawing 25] It is drawing showing another example of a non-manifold object.
[Drawing 26] It is drawing showing coding of the initial entry by the toroidal graph.
[Drawing 27] It is drawing showing the compression method using prediction of geometric information.
[Drawing 28] It is the block diagram of the object coding equipment concerning the gestalt of operation.
[Drawing 29] It is the block diagram of the object decode equipment concerning the gestalt of operation.
[Description of Notations]
10 C Node
14 C Edge
16 ANYURASU
18 2-dimensional Cel
100 Object Coding Equipment
104 Object Acquisition Section
106 Function Definition Section
108 Zero Definition Part
110 Distance Calculation Section
112 Configuration Element Decomposition Section
114 Coding Section
116 Geometric Compression Zone
118 Phase Compression Zone
120 Coded Data Output Section
200 Object Decode Equipment
202 Coded Data Acquisition Section
204 Configuration Element Extract Section
206 Decode Section
208 Geometric Decode Section

210 Phase Decode Section
212 Decode Data Output Section

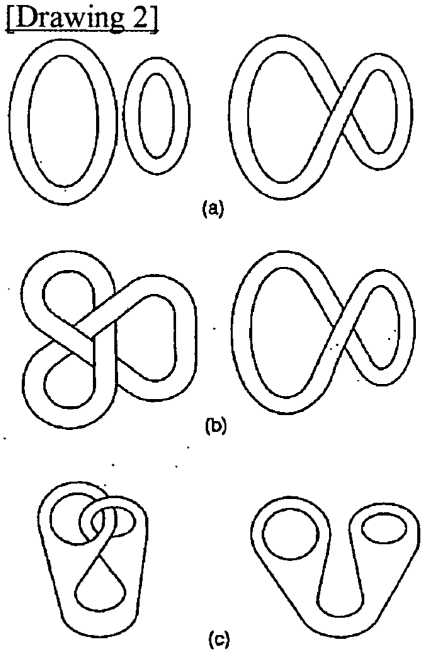
[Translation done.]

DRAWINGS

[Drawing 1]



[Drawing 2]



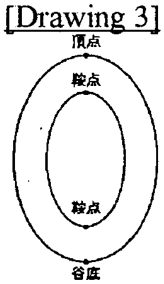
[Drawing 6]

```
program operators(input, output);
constam
          enabled = true;
          disabled = false;
          inside = true;
          outside = false;
          end_of_list = -1;
type
          contour_number = 0..max_contour_number;
          child_list = array[1..maxchildren] of contour_number;
          pointer_to_child_list = ↑ child_list;
var
          children: array[contour_number] of pointer_to_child_list;
          parent#: array[contour_number] of contour_number;
          number of children: array[contour_number] of integer;
          most_recently_created#: contour_number;
          contour_status: array[contour_number] of boolean;
```

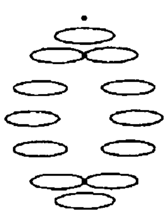
[Drawing 7]

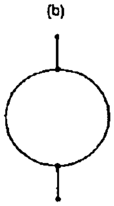
```
procedure add_listed_children(n:contour_number;clist:pointer_to_child_list);
          {details are omitted}
procedure remove_listed_children(n:contour_number;clist:pointer_to_child_list);
          {details are omitted}
function are_children(n:contour_number;clist:pointer_to_child_list);boolean;
          {details are omitted}
function in_list(n:contour_number;clist:pointer_to_child_list);boolean;
          {details are omitted}
function list_containing_only(n:contour_number):pointer_to_child_list;
var       n_as_list: pointer_to_child_list;
begin
          new(n_as_list);
          n_as_list ↑[1]:= n;
          n_as_list ↑[2]:= end_of_list;
          list_containing_only:= n_as_list;
end;
```

[Drawing 3]

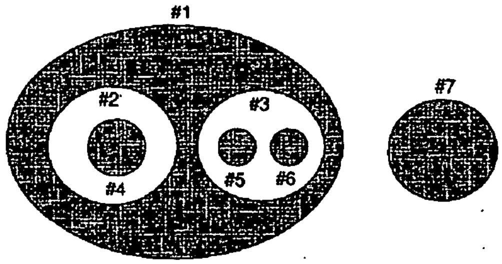


(a)

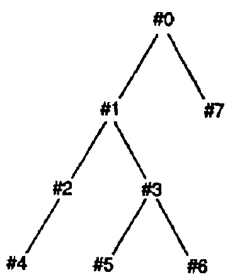

(b)


(c)

[Drawing 4]



(a)

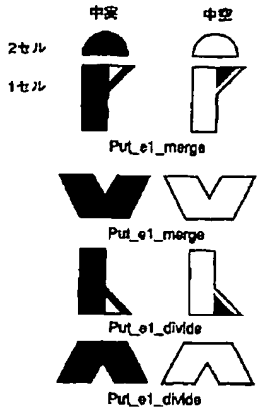


(b)

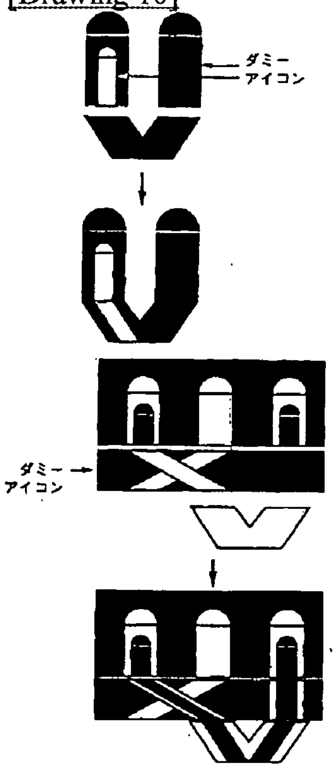
[Drawing 8]

```
a
procedure put_e2(n: contour_number);
begin
        if (contour_status[n] = disabled) then go to error;
        create_new_contour;
        add_listed_childred(n,list_containing_only(most_recently_created#));
end;
b
procedure put_e0(n: contour_number);
begin
        if ((contour_status[n] = disabled) or not all_successor_disabled(n))
              then goto error;
        contour_status[n]:= disabled;
end;
c
procedure put_e1_divide(n:contour_number); clist: pointer_to_child_list; inside:boolean);
begin
        if ((contour_status[n] = disabled) or (contour_status[parent#[n]]=disabled))
              then goto error;
        create_new_contour;
        add_listed_children(most_recently_created#, clist);
        if(not inside and are_children(parent#[n], clist)
        and not in_list(n, list)) or (clist = nil)) )
              then begin
                 remove_listed_children(parent#[n], clist);
                 add_listed_children(n,list_containing_only(most_recently_created#));
              end
        else if (inside and(are_children(n, clist) or (clist = nil)))
              then begin
                 remove_listed_children(n, clist);
                 add_listed_children(parent#[n],list_containing_only(most_recently_created#));
              end
        else go to error;
end;
d
procedure put_e1_merge(c1:contour_number; c2:contour_number);
begin
        if ((contour_status[c1] = disabled) or (contour_status[c2] = disabled))
              then goto error;
        if (c1 = parent#[c2]) then
              add_listed_children(parent#[c1], children[c2]);
        else if (parent#[c1] = parent#[c2] then
              add_listed_children(c1, children[c2]);
        else go to error;
        remove_listed_child(parent#[c2], list_containing_only(c2));
        contour_status[c2]:= disabled;
end;
```

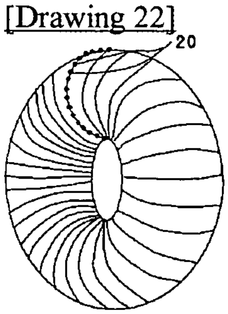
[Drawing 9]



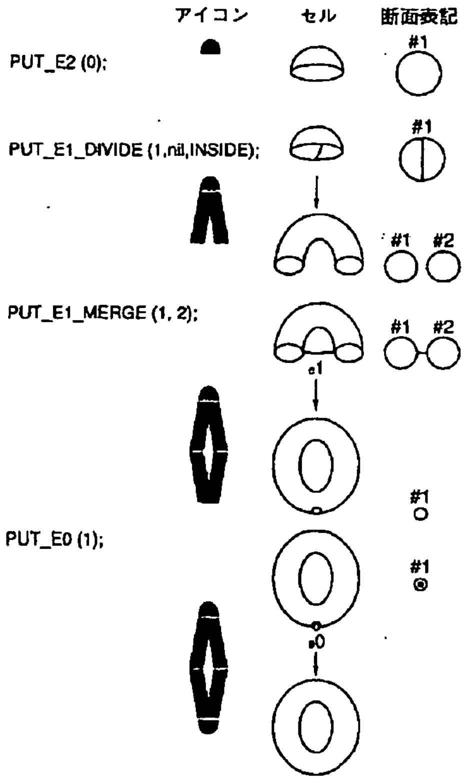
[Drawing 10]



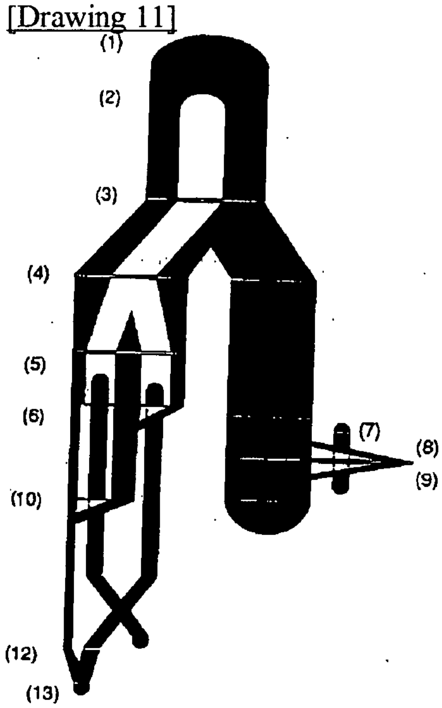
[Drawing 22]



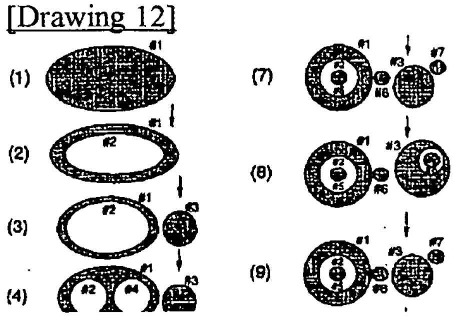
[Drawing 5]

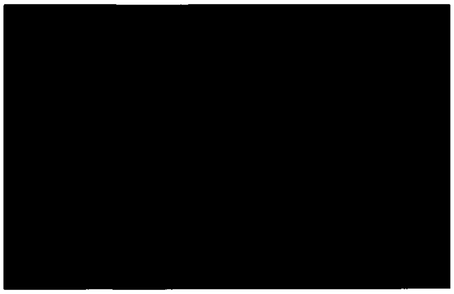


[Drawing 11]



[Drawing 12]

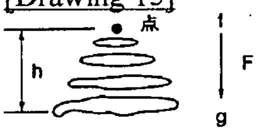




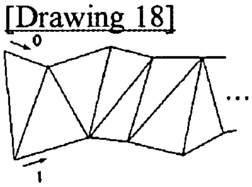
[Drawing 13]

```
1. PUT_E2(0);
2. PUT_E2(1);
3. PUT_E1_DIVIDE(1, nil, INSIDE);
4. PUT_E1_DIVIDE(2, nil, INSIDE);
5. PUT_E2(2); PUT_E2(4);
6. PUT_E1_MERGE(1, 4);
7. PUT_E2(0);
8. PUT_E1_DIVIDE(3, list_containing_only(7), OUTSIDE);
9. PUT_E1_MERGE(3, 8); PUT_E0(7); PUT_E0(3);
10. PUT_E1_MERGE(1, 2);
11. PUT_E0(5);
12. PUT_E1_MERGE(1, 6);
13. PUT_E0(1);
```

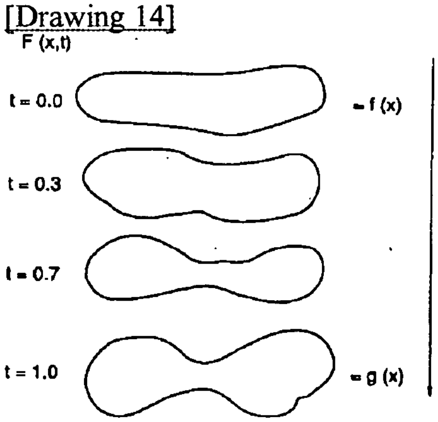
[Drawing 15]



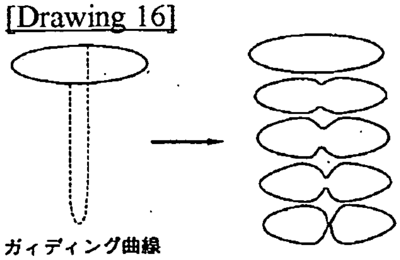
[Drawing 18]



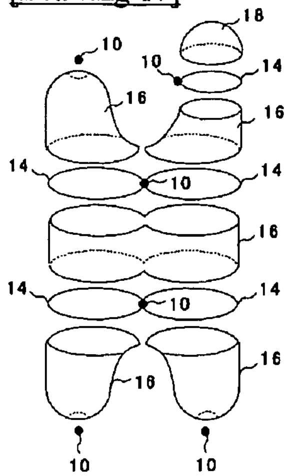
[Drawing 14]



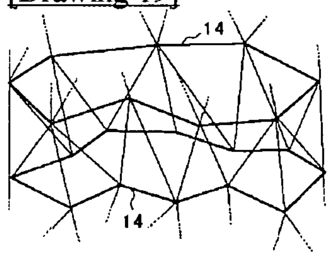
[Drawing 16]



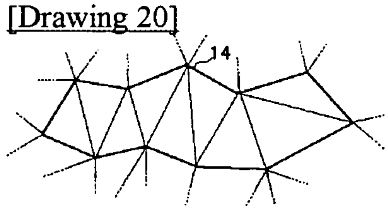
[Drawing 17]



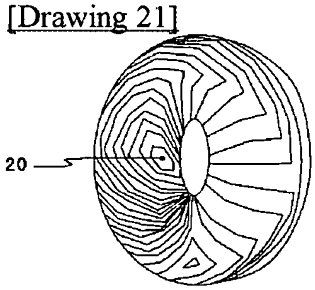
[Drawing 19]



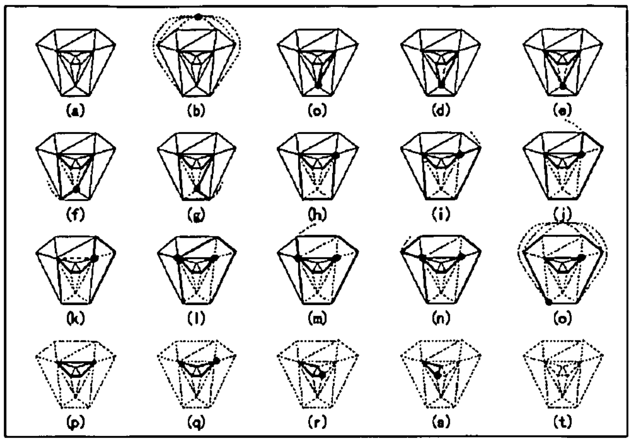
[Drawing 20]



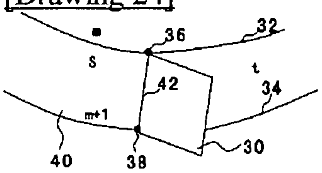
[Drawing 21]



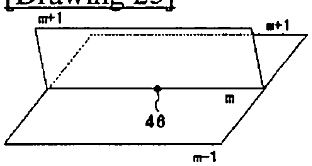
[Drawing 23]



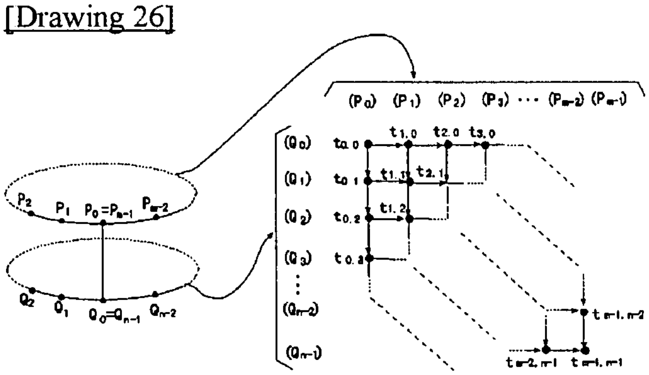
[Drawing 24]



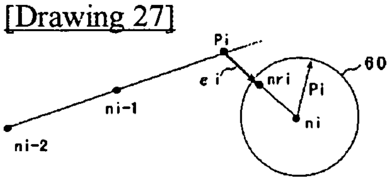
[Drawing 25]



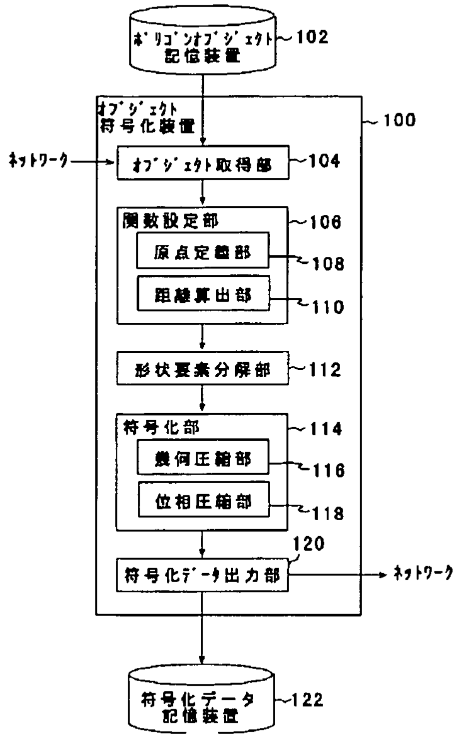
[Drawing 26]



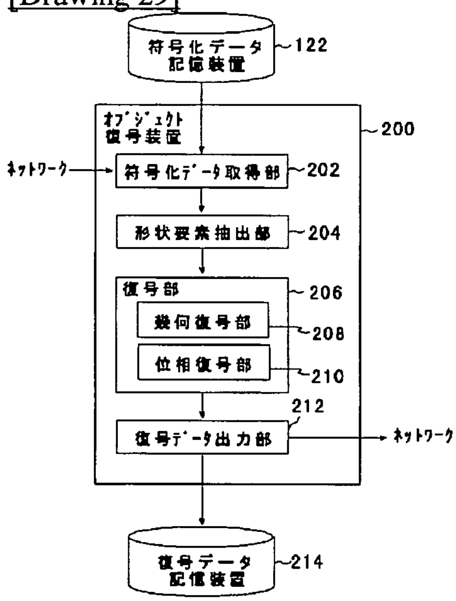
[Drawing 27]



[Drawing 28]



[Drawing 29]



[Translation done.]